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Nitrogen Availability from Potato-Processing Wastewater for Growing Corn

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ABSTRACT

A line source sprinkler was used to irrigate corn (*Zea mays* L.) plots with potato (*Solanum tuberosum* L.)-processing wastewater in 1979, 1980, and 1981. Nitrogen applications ranged from about 4 to 600 kg/ha. Corn yields were measured for each row, the grain and stalks were analyzed for total N, and N uptake was calculated. The plots were split by years, one-third of the area was fertilized with wastewater 3 y, one-third 2 y, and one-third 1 y. This allowed evaluation of current and residual value of wastewater fertilization. Corn responded well to wastewater fertilization, with N applications in the wastewater increasing corn yields with increasing increments of N up to about 200 to 250 kg/ha annually, and corn grain yields ranged up to about 12 Mg/ha. Yield comparisons were made with plots fertilized with ammonium nitrate fertilizer. We determined that potato-processing wastewater N was almost equal to ammonium nitrate N for growing corn. Wastewater applications that will apply approximately 200 to 250 kg N/ha annually should be optimum for growing corn on this soil. Wastewater N from potato processing has good residual and carry-over for 1 y but under conditions of this experiment did not carry over for more than 1 y. Whether the excess N was lost from denitrification or leaching was not determined.

Additional Index Words: **line source sprinkler, residual nitrogen, corn grain.**

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Irrigating with food-processing wastewater for growing crops is an established practice used by a large segment of the food processing industry (2, 4, 5, 6, 7, 8, and 11). In many existing systems, emphasis has been placed on disposing of wastewater with maximum applications of both the wastewater and included plant nutrients. Large amounts of wastewater and nutrients from potato (*Solanum tuberosum* L.)-processing operations have been applied to land with up to 550 cm of water and 2550 kg N/ha in 1 y (10). These seemingly excessive applications have not always created groundwater pollution problems, but in some cases have promoted almost total denitrification because of the anaerobic conditions in the soil related to the high water applications and the high energy content of the organic constituents of the wastewater (9). Well-managed wastewater irrigation fields growing grass for hay or forage look good and yield well because of the heavy fertilization with wastewater nutrients. Consequently, there has been interest from farmers in obtaining wastewater for crop irrigation and fertilization in areas adjacent to fields already irrigated with wastewater. With this developing interest in utilizing wastewater for its nutrient value, a need was seen for evaluating potato-processing wastewater and determining its potential nutrient value for growing crops.

The objectives of this research were to compare potato-processing wastewater and NH_4NO_3-N sources for corn (*Zea mays* L.) production and thereby evaluate the wastewater as a N source.

MATERIALS AND METHODS

A field plot area was selected where both potato-processing wastewater and irrigation water were available. The wastewater was pumped to the plot area through a pipeline from a potato-processing plant nearby. An area 30.5 m wide by 183 m long containing 40 rows of corn of Moulton fine sandy loam soil (mixed mesic Typic Haplaquoll) near Caldwell, Idaho was irrigated with wastewater using a line source sprinkler in the center of the plot running the length of the plot. Sprinkler nozzles were spaced at 6-m intervals. Sixty rain gauges were installed in three rows of 20 across the plot in alternate corn rows to measure wastewater applications and the water was sampled during each irrigation to determine the N and chemical oxygen demand (COD) contents of the wastewaters. The total N content of the wastewater averaged 76 mg/L with < 2 mg/L NO_3-N. Nitrogen in the wastewater applied to the plots ranged from 4 to 600 kg/ha (Table 1). Wastewater was applied five times in 1979 during the growing season and twice each year before planting corn in 1980 and 1981. During the first year the entire plot area was irrigated with wastewater; in the second year 122 m of length was irrigated and the 61 m remaining was left without wastewater irrigation for residual fertilization evaluation; in the third year 61 m of the plot was irrigated with wastewater, 61 m was evaluated for residual following 2 y of wastewater irrigation, and 61 m was evaluated for residual fertility value following 1 y of irrigation with wastewater. Each 61 m plot area was divided into three areas of 20 m each for sampling. These served as replications for statistical analyses. An adjoining set of plots with the same soil and cropping history, 10 by 23 m each, was fertilized with NH_4NO_3 to provide 100, 200, or 300 kg N/ha annually. Each plot was split to fertilize one-third of the area with one, one-third with two, and one-third with three annual applications of fertilizer during the experiment for residual N evaluation. These plots were arranged in a randomized block design replicated three times.

All of the experimental area was irrigated in the furrows between rows with Boise River water to meet the water requirements of the corn crop and to remove the water variable imposed by the wastewater irrigation. In 1979 the wastewater was applied in the early spring before planting and during the growing season to apply the desired amount of N. The following 2 y one irrigation was applied in the fall following harvest and another in the spring before planting. The excess water applied by wastewater irrigation in the center of the plots caused some extra leaching. Previous research (10) showed that the organic constituents of wastewater were removed from the water almost quantitatively in 60 cm of soil and would not leach. Therefore, the relatively uniform irrigations with river water were considered to eliminate the water variable for this experiment.

The plots were treated with Atrex and Dual postemergence at recommended rates for weed control. Corn was grown on the plot areas for 3 y, harvested at maturity, and yields of corn grain and stalks were determined separately. At harvest, three 3-m row sections were cut by hand from each of 40 rows for each wastewater irrigation treatment, weighed, the ears removed, bagged, and weighed. The stalks were run through a forage chopper and sampled for moisture and chemical analysis. The stalk samples and ears were dried in an oven at 60°C, the corn shelled, and both corn and stalks were ground and analyzed for total N by a Kjeldahl procedure (1). The cobs were discarded. The corn rows were numbered from 1 to 20, starting at the center of the plot and going to the outside row, which was number 20, on each side of the plot. Corn varieties grown on the plots and adjacent area were 'Greenway 55' in 1979 and 'Pioneer 3901' in 1980 and 1981. Plot preparation, planting, cultivation, irrigation, and harvest after plot samples were removed were performed by the cooperator.

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Table 1—Wastewater and N applied to plot area through a line source sprinkler.

Corn row	1979 Wastewater	1979 N	1980 Wastewater	1980 N	1981 Wastewater	1981 N
	cm	kg/ha	cm	kg/ha	cm	kg/ha
1	71.8	600	45.7	434	50.4	407
2						
3	56.0	468	49.4	439	51.5	412
4						
5	55.2	447	47.6	425	49.6	396
6						
7	47.7	404	38.8	346	43.0	343
8						
9	45.0	378	33.2	298	40.2	319
10						
11	35.8	303	28.1	251	32.9	262
12						
13	26.6	229	19.5	174	23.8	189
14						
15	13.8	120	12.1	106	14.5	115
16						
17	5.2	46	4.5	39	5.6	45
18						
19	0.4	4	0.7	6	0.6	4
20						

Table 2—Corn grain yield from potato-processing wastewater irrigation field in 1979, 1980, and 1981 at Caldwell, Idaho.

	Harvest year					
	1979	1980		1981		
	Years fertilized					
Corn row	1979	1979–1980	1979	1979–1980–1981	1979–1980	1979
	Corn yield					
	Mg/ha					
1	9.73 cd*	11.36 fgh	11.36 def	7.41†	4.90†	4.46†
2	10.29 cd	14.00 i	12.37 f	5.90	5.08	3.83
3	9.35 cd	12.24 gh	11.61 ef	6.09	4.90	4.46
4	10.73 cd	12.87 hi	10.36 def	6.15	4.83	4.58
5	8.79 bcd	12.93 hi	11.74 ef	6.15	5.52	5.52
6	11.61 d	11.55 fgh	10.48 cde	6.97	5.27	5.65
7	8.79 bcd	12.62 hi	11.05 def	7.85	5.21	5.02
8	8.35 bcd	11.55 fgh	10.73 de	7.28	4.96	5.08
9	10.48 cd	13.06 hi	10.17 cde	7.34	5.52	5.08
10	7.97 bc	12.48 ghi	10.86 def	7.66	5.40	4.83
11	11.11 cd	11.42 fgh	11.05 def	6.21	4.83	3.14
12	10.98 cd	10.92 efg	10.48 cde	6.53	4.52	4.71
13	10.36 cd	10.42 def	10.73 de	5.59	3.51	4.64
14	9.79 cd	9.60 cde	10.48 cde	4.52	3.14	4.21
15	7.91 bc	9.16 bcd	9.67 cd	5.52	3.83	4.64
16	7.66 bc	7.97 abc	8.98 bc	3.20	2.20	2.64
17	5.52 ab	9.10 bcd	7.97 ab	5.21	3.89	4.52
18	5.96 ab	7.78 ab	8.10 ab	4.77	3.89	4.64
19	4.02 ab	7.16 a	6.90 a	4.27	3.64	4.27
20	3.89 a	8.66 abc	7.53 ab	4.02	3.77	4.64
Mean	8.10	10.86 b	10.17 a	5.90 b	4.46 a	4.52 a

* Numbers in columns followed by different letters are different at the 95% probability level. Means were compared by harvest years.
† No statistical differences were observed in these columns.

The wastewater N applications shown in Table 1 were calculated from the N concentration and amount of wastewater collected in the rain gauges. The gauges were placed in alternate rows; therefore, the application rates for N were calculated for every other row. The applications to both sides of the sprinkler line were averaged for inclusion in the tables. The data were analyzed by analyses of variance and compared by Duncan Multiple Range Tests (3). Phosphorus and potassium analyses of potato-processing wastewater as reported by Smith et al. (10) averaged 13 and 135 mg/L.

Table 3—Nitrogen recovered in corn grain grown on a field irrigated with potato-processing wastewater in 1979, 1980, and 1981 at Caldwell, Idaho.

	Harvest year					
	1979	1980		1981		
	Years fertilized					
Corn row	1979	1979–1980	1979	1979–1980–1981	1979–1980	1979
	N recovered					
	kg/ha					
1	146 cd*	171 hi	160 k	87 ab	50 ab	48 a
2	157 cd	196 j	161 k	65 cdef	54 a	46 ab
3	138 cd	180 ij	152 jk	63 cdef	46 ab	42 ab
4	158 cd	176 hij	138 hi	64 cdef	54 a	44 ab
5	128 bcd	173 hi	146 ij	67 cde	52 ab	49 a
6	168 d.	146 ef	119 e	81 abc	52 ab	56 a
7	131 bcd	154 fgh	129 fgh	91 a	50 ab	49 a
8	124 bcd	154 fgh	126 efg	77 abcd	47 ab	52 a
9	149 cd	167 ghi	118 e	78 abcd	52 ab	50 a
10	120 bcd	171 hi	129 fgh	94 a	50 ab	49 a
11	164 cd	152 fgh	135 gh	74 bcd	52 ab	38 ab
12	166 cd	140 ef	133 fgh	77 abcd	47 ab	55 a
13	157 cd	129 de	132 fgh	62 def	36 abc	52 a
14	143 cd	114 cd	123 ef	48 fg	33 bc	48 a
15	117 bc	106 bc	108 d	55 ef	36 abc	48 a
16	115 bc	91 ab	96 c	33 g	21 c	28 b
17	72 a	100 abc	86 b	50 fg	38 abc	46 ab
18	84 ab	84 a	86 b	48 fg	41 ab	49 a
19	54 a	78 a	69 a	40 g	38 abc	45 ab
20	50 a	95 abc	81 b	38 g	36 abc	49 a
Mean	127	139 b	121 a	65 b	44 a	47 a

* Numbers in columns followed by different letters are different at the 95% probability level. Means were compared by harvest years.

RESULTS

Corn grain yields in both 1979 and 1980 were increased with increasing wastewater N fertilization up to about 200 to 250 kg N/ha with optimum wastewater fertilization yielding approximately 10 Mg of corn grain per ha (Table 2). The extra N added to rows 1 to about 13 gave no further yield increase. Yields were somewhat higher in 1980 than in 1979 but decreased greatly in 1981. Corn grain yields in 1981 were probably depressed by an early season weed infestation that was cleaned out of the plots by hand weeding. Also, the general corn yields for the area were somewhat lower in 1981 than 1980 because of seasonal differences. In 1981 the only significance in the statistical analyses was the difference between current years and residual fertilization. The 1981 fertilization produced higher yields, even when very high amounts of N had been applied in previous years in the wastewater irrigations. At the high wastewater N applications, the corn received much more N than it could assimilate, and N applications above the 200 to 250 kg/ha rate, even up to 600 kg N, were probably not responsible for variations in yield.

Nitrogen uptake in the corn followed similar trends to total corn yields in all 3 y (Table 3). The N uptake increased up to about the 200 kg/ha wastewater N fertilization level. Nitrogen uptake in the residual evaluation areas in 1981 were lower than the 1981 fertilized plot areas. In the two residual areas, significance from wastewater fertilization had disappeared.

On the average, N uptake in the corn and stalks decreased from 1979 to 1980 to 1981 and N uptake in the

Table 4—Nitrogen recovered in corn and stalks from a field irrigated with potato-processing wastewater in 1979, 1980, and 1981 at Caldwell, Idaho.

	Harvest year					
	1979	1980		1981		
	Years fertilized					
Corn row	1979	1979–1980	1979	1979–1980–1981	1979–1980	1979
	N Recovered					
	kg/ha					
1	259	238 h*	236 i	110 ac	68 ab	65 ab
2	287	244 h	216 ghi	84 defg	69 ab	62 abc
3	232	240 h	221 hi	89 def	64 ab	57 abc
4	267	240 h	213 fghi	92 cde	76 a	59 abc
5	222	208 efgh	180 defgh	89 def	71 ab	66 ab
6	279	186 def	170 cde	109 abc	71 ab	74 a
7	218	171 cde	171 def	113 ab	69 ab	63 abc
8	233	197 efg	174 def	102 abcd	67 ab	67 ab
9	260	214 fgh	164 bcde	100 abcd	69 ab	66 ab
10	224	228 gh	194 efgh	119 a	69 ab	64 ab
11	282	194 efg	196 efgh	95 bcde	67 ab	53 bc
12	280	195 ef	222 hi	102 abcd	62 ab	69 ab
13	276	177 de	192 efgh	89 def	55 bc	67 ab
14	229	152 bcd	178 defg	71 fgh	53 bc	64 ab
15	196	151 bcd	159 abcde	77 efg	53 bc	64 ab
16	208	130 ab	140 abcd	55 h	39 c	44 c
17	120	138 abc	130 abc	68 fg	53 bc	62 abc
18	160	117 ab	126 ab	67 gh	56 abc	66 ab
19	105	113 a	119 a	56 h	55 bc	62 abc
20	84	132 ab	126 ab	57 h	52 bc	66 ab
Mean	220	184 b	176 b	87 a	62 a	63 a

* Numbers in columns followed by different letters are different at the 95% probability level. Means were compared by harvest years.

Table 5—Corn stalk yields from a field irrigated with potato-processing wastewater in 1979, 1980, and 1981 at Caldwell, Idaho.

	Harvest year					
	1979	1980		1981		
	Years fertilized					
Corn row	1979	1979–1980	1979	1979–1980–1981	1979–1980	1979
	Corn stalk yields					
	Mg/ha					
1	4.84	4.37	5.42	5.92	5.31	5.31
2	5.67	3.38	4.26	5.20	4.93	4.75
3	3.23	4.08	5.27	6.10	5.81	4.77
4	4.56	4.50	5.81	6.16	6.50	4.64
5	4.37	2.67	3.45	5.85	6.19	5.34
6	3.86	3.20	4.42	6.50	5.78	5.27
7	3.76	1.66	3.70	6.23	5.67	4.35
8	5.26	3.23	4.12	6.03	6.03	4.91
9	4.76	3.63	3.97	5.78	5.63	5.20
10	5.64	4.01	5.27	6.59	6.21	4.84
11	6.08	3.18	5.11	5.51	5.22	4.39
12	6.39	4.21	6.75	5.85	4.97	4.91
13	6.54	3.90	4.91	6.01	4.93	4.95
14	4.64	3.23	4.60	5.29	5.31	4.71
15	5.09	3.72	4.46	6.01	5.09	4.91
16	9.44	3.41	4.19	5.49	4.62	4.42
17	5.13	3.45	4.08	5.16	4.46	5.22
18	–	3.09	3.70	4.84	4.06	5.45
19	3.58	3.16	4.91	4.60	4.84	4.44
20	3.96	3.36	4.28	5.00	4.73	5.27
Mean	5.09	3.47 a*	4.60 b	5.72 a	5.31 b	5.31 b

* Mean comparisons by years are different at the 95% probability when followed by different letters.

residual plots was less than in the wastewater-fertilized areas (Table 4). Generally, N uptake increased from row 20 to row 13 with increasing wastewater N applications for the 3 y. Differences in N uptake at higher N applications is apparently random error. The statistical trends for these data are about the same as those for the data from the corn and corn stalk N shown separately.

While 1980 corn yields were much higher than the other years, the stalk yields for that year were lower than the other 2 y, indicating that there is little if any correlation between stalk and corn grain yields (Table 5). There were no statistically significant differences between stalk yields from rows representing differences in wastewater N applications. The corn grain yields responded to the wastewater fertilization but the stalks did not. This lack of yield response in the corn stalks probably resulted from low fertility that produced good stalk growth, but was not sufficient to produce maximum ear growth or corn grain yield in the outer rows.

While stalk yield was not significantly influenced by N in the wastewater applications, there was a difference in N uptake in the stalks (Table 6). Nitrogen uptake increased from the lowest wastewater fertilization to about row 13 with 229 kg wastewater N application in 1979. In the following years and in the residual N evaluation areas, N uptake in the stalks was not significantly influenced by wastewater N applications. The N in the stalks in 1979 averaged about 95 kg/ha and in following years was reduced to half that value or less.

It should be noted that from time to time differences in observations for individual rows appear to be statis-

Table 6—Nitrogen recovered in corn stalks grown on a field irrigated with potato-processing wastewater in 1979, 1980, and 1981 at Caldwell, Idaho.

	Harvest year					
	1979	1980		1981		
	Years fertilized					
Corn row	1979	1979–1980	1979	1979–1980–1981	1979–1980	1979
	N Recovered					
	kg/ha					
1	113 cd*	66 b	76 b	21 abcd	18 a	18 a
2	130 d	48 ab	56 ab	25 abc	16 a	16 a
3	94 cd	61 b	69 b	26 ab	19 a	15 a
4	109 cd	64 b	75 b	28 a	21 a	15 a
5	94 cd	35 ab	34 a	21 abcd	19 a	17 a
6	111 cd	40 ab	52 a	28 a	20 a	18 a
7	87 bcd	20 a	43 a	24 abcd	19 a	12 a
8	109 cd	44 ab	48 a	25 abc	19 a	16 a
9	111 cd	47 ab	46 a	22 abcd	18 a	16 a
10	104 cd	56 b	64 ab	24 abcd	19 a	15 a
11	119 cd	41 ab	62 ab	21 ab	16 a	15 a
12	114 cd	54 ab	89 b	25 abc	16 a	16 a
13	119 cd	48 ab	61 ab	27 ab	19 a	15 a
14	85 bcd	39 ab	55 ab	22 abcd	20 a	16 a
15	80 abcd	44 ab	52 a	22 abcd	17 a	16 a
16	93 bcd	40 ab	45 a	22 abcd	18 a	16 a
17	48 ab	38 ab	44 a	19 cd	15 a	16 a
18	76 abc	33 ab	39 a	19 cd	15 a	18 a
19	52 ab	35 ab	50 a	17 d	16 a	17 a
20	34 a	40 ab	46 a	19 cd	16 a	17 a
Mean	94	45 a	55 b	22 a	18 a	16 a

* Numbers in columns followed by different letters are different at the 95% probability level. Means were compared by harvest years.

Table 7—Corn grain yield and N recovery from ammonium nitrate–fertilized plots at Caldwell, Idaho.

N Fertilizer			Corn grain yield			N Recovery in corn and stalks		
1979	1980	1981	1979	1980	1981	1979	1980	1981
kg/ha			Mg/ha			kg/ha		
0	0	0	4.58	6.65 a*	3.20 a	63	77 a	63 a
100	0	0	8.85	6.47 a	4.02 a	131	76 a	58 a
200	0	0	10.23	7.47 a	4.96 a	149	92 a	98 ab
300	0	0	9.98	8.79 ab	3.95 a	156	105 a	69 a
100	100	0		6.78 a	6.78 b		90 a	132 abc
200	200	0		8.54 a	7.09 b		128 ab	166 bc
300	300	0		10.86 b	7.47 b		161 b	161 bc
100	100	100			4.20 a			93 ab
200	200	200			7.59 b			168 bc
300	300	300			7.66 b			210 c

* Numbers in columns followed by different letters are different at the 95% probability level.

tically significant at the higher wastewater N application rates. Even though there were trends or individual numbers that showed statistical difference, these values have little meaning apart from the general level because the corn crop in rows 1 to 10 received N applications in the wastewater in excess of that required for growing the crop. Therefore, it must be assumed that any differences that existed in the yields at the higher fertility levels have to be attributed to random variation and not to N fertilization with wastewater.

In 1979, applications of NH_4NO_3-N up to 200 kg/ha increased corn yields (Table 7). In 1980 the plots that were fertilized only in 1979 showed a trend upward in yields from the check treatments to the 300-kg N treatments, but no significant differences were observed. The plots that received 300 kg N/ha for both 1979 and 1980 had higher corn yields than the plots receiving lower rates that were not different from each other, with yields up to about 10 or 11 Mg/ha. The maximum corn yields on the ammonium nitrate–fertilized plots in 1981 were about 3 Mg lower than the maximum yields in 1980. The corn fertilized in 1979 and 1980 had fertility carryover in 1981 that increased slightly with increasing rates, causing a trend toward better yields at the higher N rates. The corn fertilized the 3 y had sufficient N for excellent yields but some other factor limited yields. The amount of N in the corn grain showed similar trends to yields with N uptake increasing to the intermediate rate of N application in 1979 and no differences in N uptake for the plots that were cropped a second year without additional N. Nitrogen uptake in the corn grain in 1980 was greater for the 200 and 300 kg/ha application rates than the check, the residual plots, or the 100-kg N/ha rates.

Table 8 shows the relative N recovery rates from the various wastewater N applications by calculating N recovery by rows of corn representing four fertilization rates. The rows selected for evaluation were row 3, representing the highest fertilization rates; row 11, representing intermediate high rates; row 13, representing the average maximum application at which N response was observed; and row 15, representing relatively low N applications. The first line of data for each set shows N uptake in the crop (both stalks and corn grain). The next line of data shows a check plot N uptake that represents the N recovered without fertilization. These figures were taken from check plot N uptake from the NH_4NO_3–fertilized plot areas. The third line is

Table 8—An analysis of N uptake in corn and stalks from a field irrigated with potato-processing wastewater at Caldwell, Idaho.

	Wastewater N applied			Harvest year					
				1979	1980		1981		
				Years fertilized					
	1979	1980	1981	1979	1979–1980	1979	1979–1980–1981	1979–1980	1979
	kg/ha			N (kg/ha)					
Row 3	468	439	412						
N uptake in crop				232	240	221	89	64	57
N in check crop				63	77	77	63	63	63
N from wastewater				169	163	144	26	1	−6
N applied and residual				468	738	299	1087	575	155
N from wastewater, %				36.1	22.0	48.1	2.4	0	0
Row 11	302	251	262						
N uptake in crop				282	194	196	95	67	53
N in check crop				63	77	77	63	63	63
N from wastewater				219	117	119	32	4	−10
N applied and residual				302	334	83	479	217	0
N from wastewater, %				72.5	35.0	100	6.7	0.5	0
Row 13	229	174	189						
N uptake in crop				276	177	192	89	55	67
N in check crop				63	77	77	63	63	63
N from wastewater				213	100	115	26	−8	4
N applied and residual				229	190	16	279	90	0
N from wastewater, %				93.0	52.6	1001	9.3	0	0
Row 15	120	106	115						
N uptake in crop				196	151	159	77	53	64
N in check crop				63	77	77	63	63	63
N from wastewater				133	74	82	14	−10	1
N applied and residual				120	106	0	147	32	0
N from wastewater, %				100	69.8	--	9.5	0	0

Table 9—An analysis of N uptake in corn and stalks from plots treated with NH_4NO_3.

	N applied, kg/ha			Harvest year					
				1979	1980		1981		
				Years fertilized					
	1979	1980	1981	1979	1979–1980	1979	1979–1980–1981	1979–1980	1979
				N (kg/ha)					
N applied	300	300	300						
N uptake in crop				156	161	105	210	161	69
N in check crop				63	77	77	63	63	63
N from NH_4NO_3				93	84	28	147	98	6
N applied and residual				300	507	207	723	423	179
N from NH_4NO_3, %				31.0	16.6	13.5	20.3	23.3	3.4
N applied	200	200	200						
N uptake in crop				149	128	92	166	168	98
N in check crop				63	77	77	63	63	63
N from NH_4NO_3				86	51	15	103	105	35
N applied and residual				200	314	114	463	263	99
N from NH_4NO_3, %				43.0	16.2	13.2	22.2	39.9	34.4
N applied	100	100	100						
N uptake in crop				131	90	76	93	132	58
N in check crop				63	77	77	63	63	63
N from NH_4NO_3				68	13	−1	30	69	−5
N applied and residual				100	132	32	219	119	32
N from NH_4NO_3, %				68.0	4.6	0	13.7	58.0	0

the N uptake in the corn and stalks from the applied wastewater. The fourth line represents the amount of fertilizer applied in the wastewater in 1979 and in each successive year the N applied in the wastewater minus the N utilized by the crop for either additional wastewater N applications or residual N evaluations from previously applied wastewater N. The fifth line is an efficiency factor.

In row 3, N recovery values were relatively low because of the high fertilizer applications in 1979 and 1980 and the relatively low corn yields in 1981. The 1979 crop utilized 36% of the applied N and the residual carryover was 50% utilized in 1980, representing 68% of the originally applied wastewater N. No additional N was absorbed by the 1981 crop. With each additional wastewater N application at the high rates, the recovery decreased.

In row 11, the 1979 crop utilized 72% of the wastewater-applied N and in 1980 the residual was utilized 100%, leaving none to carry over for the second year residual evaluation. Again, the additional wastewater N applications in 1980 and 1981 decreased the N recovery percentages as shown in Table 8. In row 13, where wastewater N fertilization seemed to be optimum, 93% of the 1979-applied wastewater N was used by the corn in that year with 100% of the residual being used the following year. The second wastewater N application on row 13 that occurred in 1980 had a lower utilization efficiency, with 53%. Fertilization in 1981 and other residual evaluations showed low efficiencies in 1981 because of relatively low yields and low N utilization.

In row 15, where wastewater N fertilization was below optimum, N utilization in 1979 appeared to be 100%. With wastewater N application for 2 y, 70% N utilization was observed and for wastewater N applications for 3 y, the utilization dropped to 10%.

An analysis of N uptake by corn fertilized with NH_4NO_3 is presented in Table 9. At the 300 kg/ha N rate, recovery in 1979 was 31% followed by lower recovery values for the following 2 y fertilization. These applications were higher than the corn crop could utilize efficiently. At the 200 kg/ha N rate, recovery in 1979 was 43% followed by values about one-half that the following 2 y. At the 100 kg/ha N rate, recovery in 1979 was 68%. The next highest recovery was 58% obtained in 1980 from 2 y fertilization with NH_4NO_3. Residual N recovery values are also reported in Table 9.

Overall N recovery in corn and stalks fertilized with NH_4NO_3 ranged from 36 to 40% for plots fertilized 3 y at the three N rates, and deviated from those figures by only a few points for plots fertilized 2 y and cropped 3 y. N recovery overall increased greatly and ranged from 42 to 81% for corn fertilized 1 y and cropped 3 y (Table 10). The low fertilization rate, while it produced high N recovery, produced low corn yields.

Comparing wastewater N and NH_4NO_3-N recovery percentages in Tables 8 and 9 shows the wastewater N recovery to be higher in most cases during the first 2 y of the experiment than the fertilizer N recovery. In 1981, the wastewater-N–treated corn plots had fairly satisfactory corn yields but the N uptake was severely depressed. There is no satisfactory explanation of this difference, and comparison between the two N sources for 1981 is fruitless.

Table 10—Overall N recovery in corn grain and stalks fertilized with ammonium nitrate and cropped 3 y.

Years fertilized					
1979–1980–1981		1979–1980		1979	
N Applied	Recovery	N Applied	Recovery	N Applied	Recovery
kg/ha	%	kg/ha	%	kg/ha	%
900	36	600	30	300	42
600	40	400	43	200	68
300	37	200	40	100	81

CONCLUSION

Nitrogen from potato-processing wastewater appears to produce a maximum corn yield with about 200 kg N/ha annually. The wastewater N produces corn growth response equivalent to that of commercial fertilizer N from ammonium nitrate. In good cropping years, wastewater fertilization may have a potential for yields somewhat better than the commercial fertilizer N source. There is some carry-over of applied wastewater N from year to year when excessive amounts are applied, but the carry-over does not appear to last > 1 y. Residual fertility value of the wastewater N, even when applied at very high rates, appears to be utilized in the second year. Whether the wastewater N that was not used by the crop was leached or denitrified was not determined.

Wastewater irrigation with potato-processing wastewater is an effective method of disposing of the wastewater and nutrients. Using the wastewater for growing crops instead of disposal in waterways reduces pollution and utilizes some of the wastewater nutrients that would otherwise be wasted. Spreading the wastewater over a large enough area to efficiently utilize the included plant nutrients is a desirable advancement in wastewater irrigation. This research will provide guidelines for more nearly optimum wastewater application and utilization of the included N for crop growth and maintenance, rather than applying maximum wastewater in the disposal mode.

LITERATURE CITED

1. American Public Health Association (APHA). 1971. Standard methods for the examination of water and wastewater. Ed. 13. APHA, New York.
2. Gurnham, C. F., and T. K. Nedved. 1974. Treatability studies of three food processing plant wastewaters. Purdue Univ. Eng. Ext. Ser. Bull. 145, part 1. p. 283–289.
3. LeClerg, E. L. 1957. Mean separation by the functional analysis of variance and multiple comparisons. USDA-ARS, ARS 20-3. Natl. Agric. Library, Beltsville, Md.
4. Loehr, R. C. 1974. Agricultural waste management, problems, processes, approaches. Academic Press, Inc., New York.
5. Meyer, J. L. 1974. Cannery waste water for irrigation and ground water recharging. Calif. Agric. 28(8):12.
6. Overman, A. R., and K. Hsiao-Ching. 1976. Effluent irrigation of rye and ryegrass. J. Environ. Eng. Div. Am. Soc. Civ. Eng. 102(EE2):475–483.
7. Pearson, G. A., W. G. J. Knibbe, and H. L. Worley. 1972. Composition and variation of waste water from food processing plants. USDA-ARS, ARS 41-186. Natl. Agric. Library, Beltsville, Md.
8. Shannon, S., M. T. Vittum, and G. H. Gibbs. 1968. Irrigating with waste water from processing plants. N.Y. State Agric. Exp. Stn., Geneva, Cornell Univ. Res. Cir. 10.
9. Smith, J. H., R. G. Gilbert, and J. B. Miller. 1976. Redox potentials and denitrification in a cropped potato processing waste water disposal field. J. Environ. Qual. 5:397–399.
10. Smith, J. H., C. W. Robbins, J. A. Bondurant, and C. W. Hayden. 1978. Treatment and disposal of potato processing wastewater by irrigation. USDA Conserv. Res. Report no. 22. Natl. Agric. Library, Beltsville, Md.
11. White, J. W., Jr. 1973. Processing fruit and vegetable wastes. p. 129–142. *In* G. E. Inglett (ed.) Symposium on Processing Agricultural and Municipal Wastes. AVI Publ. Co., Westport, Conn.